DOE GENOMICS:GTL
ACCELERATING DISCOVERY FOR ENERGY AND ENVIRONMENT
OFFICE OF SCIENCE
U.S. DEPARTMENT OF ENERGY

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Exploring Microbes for Energy and Environment

A New Age of Discovery

The vast microbial world represents an untapped but valuable resource that ultimately may provide effective ways to respond to DOE mission challenges in energy and the environment. These innovative paths include generating clean energy sources (e.g., hydrogen) as well as dramatically improving environmental remediation and industrial processes.

The DOE Genomics:GTL program combines high-throughput advanced technologies and computation with information found in the genomes of microbes to establish the broad knowledge foundation needed for developing these exciting potential applications.

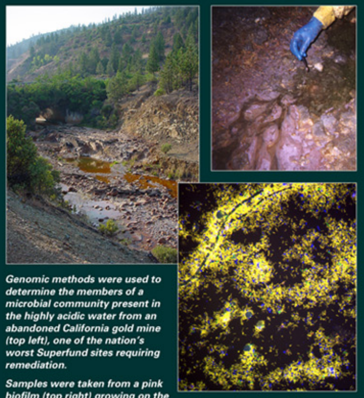
Environmental Genomics

Opening a New Window into Microbial Diversity and Function

To use microbial capabilities, scientists must first learn how microbes operate. This understanding, however, has been limited by an inability to grow the vast majority of these organisms in the laboratory. In a new turn, GTL and investigators in other programs are applying the tools of genomics to investigate entire microbial communities in their natural environments.

These environmental genomics studies isolate and analyze genome fragments directly from the environment—be it a liter of water from the open sea or a scraping from a slick film at the bottom of a highly contaminated mine.

Early analyses have revealed a broad spectrum of genomes, genes, and thus previously undiscovered functions present in these regions. Eventually, these studies will result in a multitude of new insights into the dynamics between these critical ecosystem players and their environments.



Genomic methods were used to determine the members of a microbial community present in the highly acidic water from an abandoned California gold mine (top left), one of the nation's worst Superfund sites requiring remediation.

Samples were taken from a pink biofilm (top right) growing on the surface of acid mine drainage. Group-specific fluorescence in situ hybridization (FISH, bottom right) revealed a mixture of bacteria present. After extracting and cloning DNA from the biofilm, investigators were able to reconstruct the genomes of two hardy microbes and parts of three others able to withstand the harsh conditions. Four of the microbes have never been cultivated. [Findings were reported in Nature *428, 37–43 (March 4, 2004).]*

Recent ecogenomic investigations near Bermuda in the Sargasso Sea (photo above) led to the discovery of some 150 completely new types of bacteria and more than one million new genes (about 10 times the number of genes previously studied).

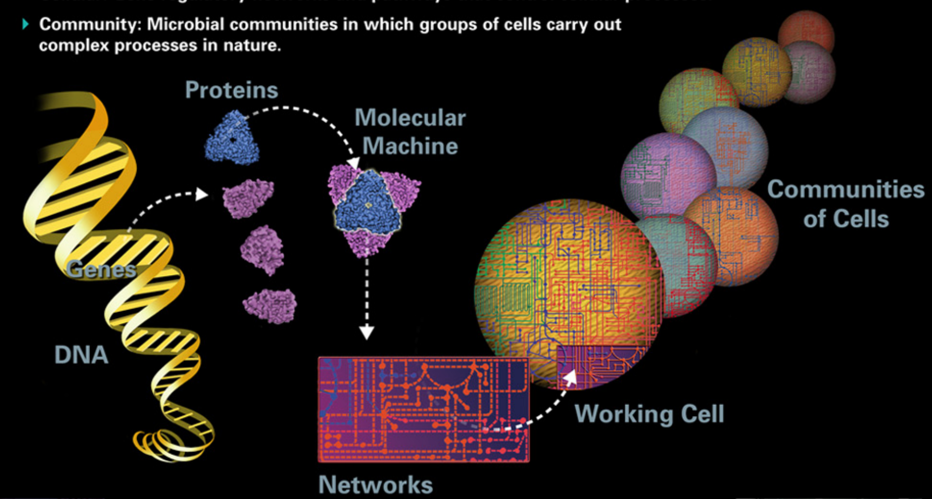
Hundreds of these genes have similarities to known genes, called rhodopsins, that capture light energy from the sun. Future analyses may provide insights into these capabilities.

Interestingly, the wealth of genes found came as a surprise to scientists who chose the nutrient-poor site as one less likely to support a broad diversity of microbes and thus easier to study. [Findings were published in Sciencexpress *(March 4, 2004).]*

Generating an Unprecedented Understanding of Living Systems

GTL scientific goals target the fundamental processes of living systems on three levels:

- Molecular: Proteins and multicomponent molecular machines that perform most of the cell's work.
- Cellular: Gene regulatory networks and pathways that control cellular processes.
- Community: Microbial communities in which groups of cells carry out complex processes in nature.

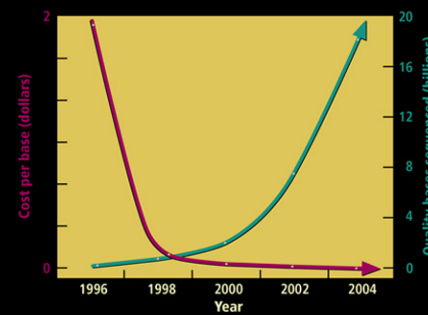


Four State of the Art Facilities to Accelerate Discovery

The DOE Offices of Biological and Environmental Research (BER) and Advanced Scientific Computing Research (OASCR) plan a set of four research facilities based on the Human Genome Project paradigm of high- throughput capabilities, computational analyses, and freely available data.

- Facility for Production and Characterization of Proteins and Molecular Tags
- Facility for Characterization and Imaging of Molecular Machines
- Facility for Whole Proteome Analysis
- Facility for Analysis and Modeling of Cellular Systems and Microbial Community Dynamics

Large-Scale Facilities Increase Productivity, Decrease Costs



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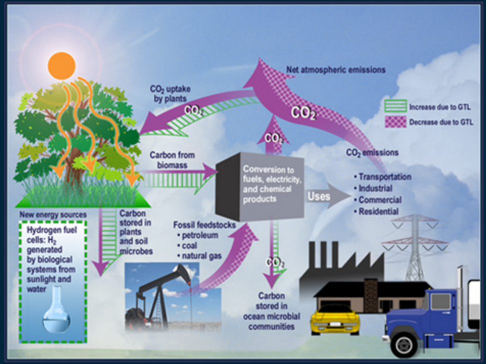
Providing the Scientific Foundation for Industrial Applications and Public Policy

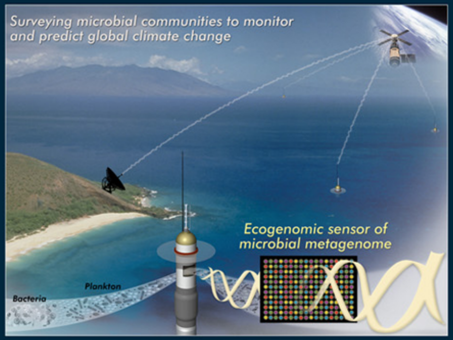
Global Impact: Energy and Environment



- Expand energy resources
- Enhance energy conservation
- Revolutionize environmental remediation
- Promote carbon management

Taking the Pulse of the Ocean

Nanoscale ecogenomic sensors are being planned to monitor microbial populations and their interactions with environmental processes, including those affected by climate change. The real-time approach envisioned by DOE for the National Oceanographic Partnership Program merges information from genome research programs with nano-technologies and smart sensors.

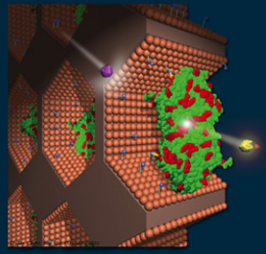


The knowledge gained will enhance understanding of the genetic diversity and functions of microbial communities and help answer key questions about their influence on ocean and terrestrial biogeochemical cycles.

Microbial sentinels of ecosystem changes may forewarn the approach of such events as a red tide or increase in Pfisteria species.

Synthetic Nanostructures Offer Microbial Functions

Learning about the inner workings of microbes and their diverse repertoire of molecular machines can lead to discovery of ways to isolate and use these components to develop new, synthetic nanostructures that carry out some of the functions of living cells.



In this figure, the enzyme organophosphorus hydrolase (OPH) has been embedded in a synthetic nanomembrane (mesoporous silica) that enhances its activity and stability. The OPH transforms toxic substances (purple molecule at left of OPH) to harmless byproducts (yellow and red molecules at right).

Applications such as this could enable development of efficient enzyme-based ways to produce energy, remove or inactivate contaminants, and sequester carbon to mitigate global climate change. The knowledge gained from GTL research also could be highly useful in food processing, pharmaceuticals, separations, and the production of industrial chemicals.

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